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The Internal Application of Chemicals to Kill Elm Trees and Prevent Bark-Beetle Attack

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CONTENTS

INTRODUCTION

For many years man has attempted to protect trees from the ravages of insects and disease through the medium of chemicals. One of the many methods tested of applying the chemicals is the introduction of the chemical solutions into the sap stream of the tree. The optimum result hoped for from this method has been to protect the living tree, but so far as is known protecting it from insect attack has never been accomplished. The method has, however, given much promise in protecting the dead timber of the treated trees from subsequent injury by insects and fungi. A recent paper by Craighead and St. George [2] includes an interesting historical résumé of this method of chemical control.

The studies reported in this circular have shown that, by the introduction of certain chemicals into the sap stream, elm trees can be killed without inducing subsequent bark-beetle attack or sprouting. In 1936 the writer began the present studies with experiments in which chemicals were introduced into living elm trees with the object of killing the trees and preventing subsequent insect attack. This was a continuum of other work conducted by the Division of Forest Insect Investigations and reported on by Craighead and St. George.[2] Par-

[1] The writer acknowledges the assistance of F. C. Craighead, in charge of the Division of Forest Insect Investigations, and of C. W. Collins, of the Morristown, N. J., laboratory in the planning and execution of these experiments. He is also indebted to E. G. Brewer, in charge of the Federal Dutch Elm Disease Eradication unit, for his cooperation in furnishing much of the assistance necessary in the field work and for his willingness to put to field test several of the more promising chemicals; and also to W. R. Douglas, G. E. Taylor, W. C. Baker, and especially A. E. Lantz, of the Morristown, N. J., laboratory staff, for their very helpful assistance in the field and laboratory work.

[2] CRAIGHEAD, F. C., and ST. GEORGE, R. A. EXPERIMENTAL WORK WITH THE INTRODUCTION OF CHEMICALS INTO THE SAP STREAM OF TREES FOR THE CONTROL OF INSECTS. Jour. Forestry 36: 26–34. 1938.

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ticular emphasis was placed on the control of two bark beetles (*Scolytus multistriatus* Marsham and *Hylurgopinus rufipes* (Eich.)) which are the most important known insect vectors of the Dutch elm disease fungus (*Ceratostomella ulmi* Buisman) in the United States, as reported by Collins and others.[3] These experiments were continued in 1937 and 1938.

EXPERIMENTAL OBJECTIVE

One of the most difficult problems in the eradication program of the Dutch elm disease work is to find the best way to deal with the innumerable stands of wild elm trees. Many of these are in swamp areas where walking is so difficult and the canopy so interlaced that scouting for elm trees affected by the disease is costly and laborious. Other areas are mountainsides on which the elm trees are so widely scattered that to examine them annually for disease symptoms has necessitated much difficult climbing to visit relatively few trees. The principal method used to eliminate trees from such areas has been to cut and burn all the standing wild elm trees and to treat the remaining stumps chemically to prevent sprout growth. This method is both slow and costly, and its use has met with some opposition by property owners who wish to keep the wood for fuel or other purposes. To release untreated wood from such felling operations is dangerous, as such material is ideal for bark-beetle attack and development and because of this would lead indirectly to further dissemination of the Dutch elm disease fungus. It was therefore the purpose of these experiments to determine whether wild elm trees in such areas could be economically and efficiently killed by chemical injection in order to prevent sprouting, and at the same time afford protection against subsequent attack by the two elm bark beetles.

EXPERIMENTAL ARRANGEMENT

The early studies on this problem, made during the winter, spring, and summer of 1936, consisted in the introduction of solutions of several water-soluble chemicals into a limited number of living elm trees. The selection of the chemicals and the method employed were based on the results of similar studies conducted in previous years on pine trees at the Asheville, N. C., forest insects laboratory by Craighead and St. George.[4] The experiments in 1936 showed that solutions of water-soluble chemicals could be introduced into the sap stream of living elm trees. Certain of these chemicals killed the trees and gave some protection against bark-beetle attack.

With results of these first studies in mind, more comprehensive experiments were begun in December 1936 and carried through to September 1938. These studies were conducted in three large wooded areas, in which a total of some 2,500 elms were measured and tagged. During the first week of each month, from December 1936 to September 1937, inclusive, a series of trees in these plots were treated with each one of the following chemicals: A saturated water solution of copper sulfate, dry granular copper sulfate, and a saturated

[3] Collins, C. W., Buchanan, W. D., Whitten, R. R., and Hoffmann, C. H. BARK BEETLES AND OTHER POSSIBLE INSECT VECTORS OF THE DUTCH ELM DISEASE CERATOSTOMELLA ULMI (SCHWARZ) BUISMAN. Jour. Econ. Ent. 29: 169–176. 1936.

[4] See footnote 2.

water solution of sodium arsenite. The dosages used were 15, 30, 60, 90, and 120 grams of dry salt per inch diameter at breast height,[5] excepting that the 120-gram dose was not used in the treatments with the sodium arsenite solution. Each of these treatments was applied each month to five different elm trees from 3 to 12 inches in diameter, except when it became evident that further tests with any particular dosage were not warranted.

In addition to the foregoing treatments many other chemicals were applied less frequently on fewer trees. These miscellaneous chemicals are listed in table 6.

During the first week of each month from May to September, inclusive, estimates were made on the percentage of the wood dead of each standing, treated tree. These estimates were based on the condition of the foliage as indicated by visual observations. Each tree was placed in one of the following classes: A, Normal trees; B, trees with crown 10 to 80 percent dead; C, trees with crown 81 to 100 percent dead and usually with trunk or root sprouts; D, trees entirely dead.

In the falls of 1937 and 1938 sample trees from each treatment were felled for examinations for bark-beetle attack.

EXPERIMENTAL TECHNIQUE

The method used for applying chemicals in liquid form has been described by Lantz.[6] Briefly this method consists in smoothing a 12-inch band of bark around the tree at breast height and then completely girdling the xylem with chisel cuts approximately one-fourth of an inch in depth. This girdle should be kept level. A collar of rubberized fabric is then tacked around and joined to the tree just below the chisel cuts. The joint between the tree and the collar is made watertight by the use of a compound of asphaltum and asbestos. The chemical solution is then poured into this collar.

The method used for applying dry chemicals was described by Liming.[7] In brief it consists in removing a band of bark at breast height, without cutting into the xylem, and applying the dry chemical salt. The chemical is kept in place by a band of oilcloth securely nailed and sealed to prevent rains from washing away the chemical.

In all cases where dry chemical salts or their water solutions were used the dosage was based on the weight of the dry chemical. When saturated solutions were used, the concentration varied with the temperatures to which they were exposed. The dosage of liquid chemicals was measured by volume.

In making the fall examinations for bark-beetle attack only the trees that had entirely succumbed or had only a few live sprouts were considered, as neither of the two species of bark beetles can develop in live wood. These trees were felled and cut into 4-foot logs. Each log was entirely stripped of bark and the maternal tunnels of both *Scolytus multistriatus* and *Hylurgopinus rufipes* were counted. The galleries of these two species were divided into two classes, (1) maternal galleries with living larvae and (2) maternal galleries with no living larvae. Only galleries falling in the first class were considered

[5] All diameter measurements in this circular are at breast height.

[6] LANTZ, A. E. AN EFFICIENT METHOD FOR INTRODUCING LIQUID CHEMICALS INTO LIVING TREES. U. S. Dept. Agr., Bur. Ent. and Plant Quar., E-434, 4 pp., illus. 1938. [Mimeographed.]

[7] LIMING, O. N. THE DUTCH ELM DSEASE ERADICATION PROGRAM—OBJECTIVE, METHODS, AND RESULTS. U. S. Dept. Agr. Plant Dis. Rptr. Sup. 99: 18-25. 1937. [Mimeographed.]

as indicating the ineffectiveness of a chemical. General notes were also made on other types of insect attack.

A few of the trees treated with copper sulfate and sodium arsenite were examined for distribution of the chemical. These trees were felled and cut into 2-foot sections, and increment-core samples of uniform size were taken from the middle of each section. Quantitative tests for copper sulfate or sodium arsenite were made on these cores, depending on the treatment. The sampled sections were then exposed to bark-beetle attack in laboratory cages.

At the start of this experiment felled untreated elm trees were used as checks, principally to determine to what extent the two elm bark beetles were present in the study plots. Since that time other experiments have shown that trees treated with certain chemicals that did not prevent bark-beetle attack were more attractive to these beetles and therefore more suitable checks.[8]

RESULTS OBTAINED

In summarizing the results on the trees treated at the first of each month, it was found that there was no significant difference between the individual monthly treatments applied from December to April or between those applied from May to September. There was considerable difference, however, between the results of treatments applied during the nonfoliar period of December to April as compared with the results of those applied during the foliar period of May to September. These two groups are therefore studied separately.

The rate of kill, based on visual observations taken during the first week of each month, of elm trees treated with copper sulfate solution, dry copper sulfate, and sodium arsenite solution during the nonfoliar months is shown in table 1. The same information for the same treatments applied during foliar months is given in table 2. It will be noted that there is a variation in the number of trees reported on for each month. The reason for this is that some of the trees were felled from time to time for various laboratory examinations. For obvious reasons certain of the dosages were not repeated each month, as the additional information to be obtained from the use of these dosages did not warrant the additional time required to apply them.

The degree of kill of the tree and the bark-beetle control for all other chemicals applied to living elm trees are given in table 6.

In addition to the monthly observations on the rate of kill of the standing treated trees, an examination of all the stumps of the felled treated trees was made late in the summer of 1938. This examination revealed that not one of the stumps of trees treated with solutions of copper sulfate or sodium arsenite was sprouting, whereas stumps of trees treated with dry copper sulfate were, in many cases, sprouting vigorously.

The fall examinations for bark-beetle attack showed no significant increase in trees remaining in the field for two seasons over those standing only one season. For this reason these two groups of examinations have been combined.

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[8] WHITTEN, R. R., and BAKER, W. C. TESTS WITH VARIOUS ELM-WOOD TRAPS FOR BARK-BEETLES. Jour. Econ. Ent. 32: 630–634. 1939.

TABLE 1.—*Progressive condition during the first week of each month of trees treated from December 1936 to April 1937, inclusive*

Chemical	Dosage per inch of diameter	Number of trees showing indicated degree [1] of damage																																							
		1937																				1938																			
		May				June				July				August				Septembe				May				June				July				August				September			
		A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
	Gms.																																								
Copper sulphate solution	15	4	10	3	5	1	---	6	14	1	1	5	12	---	---	9	10	---	---	3	6	---	---	2	7	---	---	1	8	---	---	---	9	---	---	1	8	---	---	1	8
	30	2	6	6	11	---	---	3	22	---	---	3	22	---	---	2	23	---	---	2	13	---	---	1	14	---	---	1	14	---	---	---	15	---	---	---	15	---	---	---	15
	60	2	6	3	14	---	---	2	22	---	---	2	21	---	---	1	22	---	---	---	14	---	---	---	14	---	---	---	14	---	---	---	13	---	---	---	13	---	---	---	13
	90	1	7	4	10	---	---	2	19	---	---	---	20	---	---	---	20	---	---	---	10	---	---	---	10	---	---	---	10	---	---	---	10	---	---	---	10	---	---	---	10
	120	2	3	2	18	---	---	1	24	---	---	---	25	---	---	---	25	---	---	---	15	---	---	---	15	---	---	---	15	---	---	---	15	---	---	---	15	---	---	---	15
Sodium arsenite solution	15	3	4	4	12	---	---	1	21	---	---	---	20	---	---	---	20	---	---	---	10	---	---	---	10	---	---	---	10	---	---	---	10	---	---	---	10	---	---	1	9
	30	1	7	3	13	---	---	---	22	---	---	---	22	---	---	---	22	---	---	---	12	---	---	---	12	---	---	---	12	---	---	---	12	---	---	---	12	---	---	---	12
	60	---	5	3	16	---	---	---	24	---	---	1	21	---	---	1	21	---	---	---	12	---	---	---	12	---	---	---	12	---	---	---	12	---	---	---	12	---	---	---	12
	90	---	3	6	14	---	---	---	23	---	---	---	23	---	---	---	23	---	---	---	13	---	---	---	13	---	---	---	13	---	---	---	13	---	---	---	13	---	---	---	13
Copper sulphate (dry)	15	17	3	1	1	7	5	6	---	8	3	5	1	3	3	10	1	1	1	5	2	---	---	6	3	---	---	6	3	---	---	6	3	---	---	6	3	---	---	6	3
	30	18	5	1	1	10	3	9	3	11	2	9	3	8	1	13	3	7	1	8	3	3	1	7	6	3	1	8	5	3	1	8	5	---	1	10	6	---	1	8	8
	60	13	7	1	4	6	6	9	4	7	4	9	5	6	---	13	6	4	---	9	2	1	1	9	4	1	---	10	4	1	1	9	4	1	1	9	4	---	2	9	4
	90	16	1	3	4	8	2	5	6	6	2	8	4	4	1	9	6	3	---	6	3	3	---	4	5	---	---	4	4	2	---	5	5	1	1	5	5	---	---	3	9
	120	15	3	4	3	12	3	7	3	10	2	8	6	4	2	13	6	3	1	10	3	3	1	9	4	3	1	9	4	1	3	9	4	---	2	9	5	---	2	9	6

[1] A, normal trees; B, crown 10 to 80 percent dead; C, crown 81 to 100 percent dead and usually with trunk or root sprouts; D, trees entirely dead.

TABLE 2.—*Progressive condition during the first week of each month of trees treated from May to September 1937, inclusive*

Number of trees showing the indicated degree[1] of damage

Chemical	Dosage per inch of diameter	1937 June				1937 July				1937 August				1937 September			
		A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
	Gms.																
Copper sulphate solution	15	---	---	4	6	---	---	8	---	---	---	8	---	---	---	3	1
	30	---	---	2	8	---	---	6	4	---	---	13	5	---	---	10	3
	60	---	---	---	10	---	---	3	5	---	---	4	13	---	---	6	8
	90	---	---	---	10	---	---	1	9	---	---	4	14	---	---	2	11
	120	---	---	---	10	---	---	---	10	---	---	---	18	---	---	---	14
Sodium arsenite solution	15	---	---	---	10	---	---	2	6	---	---	6	11	---	---	2	11
	30	---	---	---	10	---	---	1	8	---	---	6	13	---	---	4	12
	60	---	---	---	10	---	---	---	9	---	---	---	9	---	---	---	5
	90	---	---	---	10	---	---	---	10	---	---	---	19	---	---	1	14
Copper sulphate (dry)	15	3	1	6	---	3	---	5	---	3	---	5	---	2	---	3	---
	30	2	1	5	2	2	2	6	---	2	---	6	1	2	---	2	---
	60	3	1	3	3	2	---	5	1	1	---	7	---	---	1	3	---
	90	2	---	4	4	2	2	4	2	5	1	11	1	2	3	4	6
	120	1	1	3	4	1	1	5	2	1	---	5	2	1	---	2	---

Chemical	Dosage per inch of diameter	1938 May				1938 June				1938 July				1938 August				1938 September			
		A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
	Gms.																				
Copper sulphate solution	15	---	---	2	2	---	---	2	2	---	---	---	4	---	---	1	3	---	---	---	4
	30	---	---	4	7	---	---	5	7	---	---	4	8	---	---	4	8	---	---	5	7
	60	---	---	1	11	---	---	1	11	---	---	2	10	---	---	2	10	---	---	1	11
	90	---	---	---	12	---	---	---	12	---	---	---	12	---	---	---	12	---	---	---	12
	120	---	---	---	12	---	---	---	12	---	---	---	12	---	---	---	12	---	---	---	12
Sodium arsenite solution	15	---	---	1	12	---	---	1	12	---	---	2	11	---	---	2	11	---	---	2	11
	30	---	---	1	15	---	---	1	15	---	---	1	15	---	---	---	16	---	---	---	16
	60	---	---	---	5	---	---	---	5	---	---	---	5	---	---	---	5	---	---	---	5
	90	---	---	---	15	---	---	---	15	---	---	---	15	---	---	---	15	---	---	---	15
Copper sulphate (dry)	15	1	---	2	2	1	1	3	---	1	---	3	1	1	---	3	1	1	---	3	1
	30	1	1	1	1	---	1	2	1	---	1	2	1	---	1	2	1	---	---	2	2
	60	---	---	4	---	---	---	4	---	---	---	4	---	---	---	4	---	---	---	3	1
	90	---	4	4	6	---	2	6	6	---	---	9	5	---	---	6	8	---	---	8	6
	120	---	---	3	---	---	---	3	---	---	---	3	---	---	---	3	---	---	---	3	---

[1] A, Normal trees; B, crown 10 to 80 percent dead; C, crown 81 to 100 percent dead and usually with trunk or root sprouts; D, trees entirely dead.

The results of bark-beetle attack in the trees treated during the nonfoliar months are given in table 3 and for trees treated during foliar months in table 4. Trees of approximately the same size were used for each treatment. Because of the manner in which these examinations were made, the results are given in percentage of 4-foot sections infested and average number of galleries per 4-foot section.

TABLE 3.—*Bark-beetle attack in elm trees treated during nonfoliar months* [1]

Treatment	Dosage per inch of diameter	Trees examined	Total 4-foot sections	Sections infested	Average number of bark-beetle galleries per section	
					Scolytus multistriatus	*Hylurgopinus rufipes*
	Grams	*Number*	*Number*	*Percent*	*Number*	*Number*
Copper sulphate solution	15	19	132	45	2.22	3.44
	30	20	136	34	.21	3.81
	60	19	132	28	.12	3.78
	90	18	148	32	.70	3.99
	120	20	139	21	.09	2.23
Sodium arsenite solution	15	19	138	14	.06	.70
	30	20	143	11	.07	.50
	60	20	114	6	0	.35
	90	15	124	5	.08	.15
Copper sulphate (dry)	15	17	103	32	.80	1.10
	30	16	127	64	5.72	30.38
	60	20	132	42	5.28	1.88
	90	18	119	49	6.24	4.87
	120	17	88	44	3.80	1.89

[1] December 1936 to April 1937 inclusive. Examinations made in September 1937 and September 1938.

TABLE 4.—*Bark-beetle attack in elm trees treated during foliar months* [1]

Treatment	Dosage per inch of diameter	Trees examined	Total 4-foot sections	Sections infested	Average number of bark-beetle galleries per section	
					Scolytus multistriatus	*Hylurgopinus rufipes*
	Grams	*Number*	*Number*	*Percent*	*Number*	*Number*
Copper sulphate solution	15	8	45	2	0.02	0
	30	18	138	2	0	.23
	60	17	133	3	0	.05
	90	17	143	2	0	.04
	120	18	137	1	.01	.01
Sodium arsenite solution	15	20	148	0	0	0
	30	19	156	0	0	0
	60	12	93	0	0	0
	90	17	148	0	0	0
Copper sulphate (dry)	15	7	53	45	2.47	10.09
	30	6	48	52	18.23	11.75
	60	8	60	28	.53	.02
	90	14	95	21	.20	.85
	120	7	50	28	1.68	2.48

[1] May 1937 to September 1937 inclusive. Examinations made in September 1937 and September 1938.

In addition to the treatments applied in the experimental plots the Federal unit engaged in Dutch elm disease eradication has made several large field applications of copper sulfate solution to living elm trees. In one location over 1,000 elm trees were treated with zinc chloride solution. To study the effectiveness of these field treatments, 50 trees in each of several of these areas were selected at random and examined for bark-beetle attack. The results of these

examinations are included in table 5. Both *Scolytus multistriatus* and *Hylurgopinus rufipes* were determined to have been present in each of these areas during the period of these studies. In considering treatments with zinc chloride solution it will be noted that there was but a slight difference in the degree of attack in the trees treated when in foliage and those treated when not in foliage. The probable reason for this is that the first treatments were applied late in April, just prior to the date the trees produced foliage.

TABLE 5.—*Bark-beetle attack found in elm trees treated by field crews* [1]

Location	Chemical	Dosage per inch of diameter	Total trees examined	Total 4-foot sections	Total sections infested	Average number of bark-beetle galleries per section	
						Scolytus multistriatus	*Hylurgopinus rufipes*
		Gms.	*Number*	*Number*	*Percent*	*Number*	*Number*
Johnsonburg, N. J	Copper sulfate	120	50	536	1	0	0.02
Watchung, N. J	do	60	50	575	[2] 4	.13	0
Lake Owassa, N. J	do	60	50	634	0	0	0
Springdale, N. J.	do	[3] 120	52	287	23	.01	1.33
West Milford, N. J	Zinc chloride	60	50	1,184	3	.03	.06
Do	do	[3] 60	50	828	5	.03	.06

[1] Only trees treated with chemical solutions are included.
[2] The infestation found in this plot was limited to narrow strips of untreated wood and was due to inefficient application.
[3] These two areas were treated while the trees were in a nonfoliar condition, all other treatments were applied to trees while in leaf.

The results obtained with other chemicals, both as to the killing of the trees and as to the prevention of bark-beetle development, are given in table 6 and more detailed data on the bark-beetle attack in trees treated with a few of the more promising of these miscellaneous chemicals are included in table 7. The only one of these chemicals that has been applied to large numbers of elm trees under field conditions is zinc chloride. It is of interest that elm wood from zinc-chloride-treated trees showed a certain amount of local inhibition to the growth of the Dutch elm disease fungus (*C. ulmi.*).[9] This inhibition to the fungus was greatly reduced in wood taken more than 1 foot from the point where the chemical was introduced into the tree, thus indicating that heavier dosages of the chemical will be necessary to produce an effect of value in a treated tree.

TABLE 6.—*Lethal effect of introducing miscellaneous chemicals into living elm trees and their efficiency in controlling bark-beetle attack*

Chemical	Effect on killing elm trees	Effect on controlling bark-beetle attack
Acetic acid (glacial) (CH_3COOH)	Fair	Good.
Aluminum chloride ($AlCl_3.6H_2O$)	Poor	([1]).
Aluminum sulfate ($Al_2(SO_4)_3$)	Fair	Poor.
Ammonium bifluoride (NH_4HF_2)	Good	Good.
Ammonium chloride (NH_4Cl)	Poor	([1]).
Ammonium phosphate ($NH_4H_2PO_4$)	do	([1]).

[1] Trees from these treatments were not examined for bark-beetle attack.

[9] MOOK P. V., in unpublished notes on work of the Division of Forest Pathology of the Bureau of Plant Industry, U. S. Department of Agriculture.

TABLE 6.—*Lethal effect of introducing miscellaneous chemicals into living elm trees and their efficiency in controlling bark-beetle attack*—Continued

Chemical	Effect on killing elm trees	Effect on controlling bark-beetle attack
Ammonium sulfate (NH_4HSO_4)	Fair	Poor.
Calcium chloride ($CaCl_2.6H_2O$)	do	Do.
Copper chloride ($CuCl_2.2H_2O$)	do	Fair.
Copper nitrate ($Cu(NO_3)_2.3H_2O$)	Good	Good.
Ferrous sulfate ($FeSO_4.7H_2O$)	Fair	Poor.
Formalin (HCHO)	Good	Fair.
Fuel oil	Poor	(1).
Lime-sulfur (33° Bé)	Fair	Poor.
Magnesium chloride ($MgCl_2.6H_2O$)	Poor	(1).
Magnesium sulfate ($MgSO_4.7H_2O$)	do	(1).
Maleic acid ($C_2H_2O_2$: $C_2H_2O_2$)	do	(1).
Methanol (CH_3OH)	Fair	Poor.
Nickel chloride ($NiCl_2.6H_2O$)	Good	(1).
Phenol (alcohol solution) (C_6H_5OH)	Fair	(1).
Pitch oil	Poor	(1).
Potassium ferricyanide ($K_3Fe(CN)_6$)	do	(1).
Potassium ferrocyanide ($K_4Fe(CN)_6.3H_2O$)	do	(1).
Potassium permanganate ($KMNO_4$)	do	(1).
Sodium chlorate ($NaClO_3$)	Good	Poor.
Sodium chloride (NaCl)	Poor	(1).
Sodium cyanide (NaCN)	Good	Fair.
Sodium dichromate ($Na_2Cr_2O_7.2H_2O$)	do	Poor.
Sodium thiocyanate (NaCNS)	Fair	Do.
Sodium thiosulfate ($Na_2S_2O_3.5H_2O$)	do	Do.
Strontium bromide ($SrBr_2.6H_2O$)	Poor	(1).
Tannic acid	do	(1).
Zinc chloride ($ZnCl_2$)	Fair	Good.
Zinc sulfate ($ZnSO_4$)	Poor	(1).

[1] Trees from these treatments were not examined for bark-beetle attack.

TABLE 7.—*Extent of bark-beetle attack in elm trees treated while in leaf with miscellaneous chemicals*

Chemical	Dosage per inch of diameter	Trees examined	Total 4-foot sections	Total sections infested	Average number of bark-beetle galleries per section	
					Scolytus multistriatus	*Hylurgopinus rufipes*
	Grams	*Number*	*Number*	*Percent*	*Number*	*Number*
Ammonium bifluoride solution	5	6	37	3	0.03	0
Do	15	6	46	0	0	0
Do	30	12	73	0	0	0
Do	60	6	28	0	0	0
Copper nitrate solution	20	4	20	0	0	0
Do	60	5	70	0	0	0
Copper chloride solution	20	2	9	22	2.22	0
Do	60	5	46	0	0	0
Zinc chloride solution	60	7	44	5	.09	0
Do	120	6	33	0	0	0

An attempt to show a correlation between the quantity of copper sulfate present in individual elm logs and the amount of bark-beetle attack in those logs was unsuccessful. The quantitative analyses of several thousand increment-core samples taken from elm trees treated with copper sulfate solution gave the following results: (1) Copper sulfate could not be recovered from samples taken over 20 to 25 feet above the point of application in trees treated between December and April, (2) copper sulfate was recovered from all parts of trees treated between May and September, (3) approximately 80 percent of the copper sulfate present in treated trees is water-insoluble, that is, it cannot be extracted by steeping in hot water, (4) approximately 90

percent of the copper sulfate present in the xylem is confined to the outer fourth inch, (5) trees allowed to stand for several months after treatment contain approximately as much copper sulfate in the inner bark as they do in the outer half inch of the xylem.

COST OF APPLICATION

The cost of impregnating living elm trees with chemical solutions varies considerably with the chemical used and the accessibility of the trees to be treated. The only data available on the cost of chemically treating living elm trees was taken from the large field applications of zinc chloride. These data are applicable to the other promising chemicals with the exceptions of the time required for making up the solutions, the volume of solution necessary per tree, and the need for noncorrosive vessels for copper sulfate solution. The data presented in table 8 on the zinc chloride application are based on 850 trees averaging 9¼ inches in diameter and growing in a fairly concentrated stand.

TABLE 8.—*Cost data on treating 850 living elm trees averaging 9.25 inches in diameter with zinc chloride solution*

Item	Cost per unit	Average cost per tree
Zinc chloride	$0.06 per pound	$0.073
Rubberized cloth (for collars)	$0.25 per yard	.063
Asphalt compound	$37.80 per ton	.007
Tacks	$8.23 per 100 pounds	.004
Labor (including crew foremen)	$0.50–0.66 per hour	.498
Transportation of men and materials	$0.05 per mile	.049
Total		.694

The tools required for chemically treating living elm trees as prescribed by Lantz [10] are one tree tape, one light hammer, one hand axe, one drawknife, one putty knife, one pencil, one liquid measure, and one short 1½-inch chisel.

DISCUSSION

Before conclusions are drawn from the foregoing experimental results, certain draw backs to the use of some of the chemical solutions must be considered. For example, copper sulfate solution has a corrosive action on most metals, ammonium bifluoride has an etching effect on glass containers, and sodium arsenite solution is highly toxic to man. Then, too, certain of the chemicals are hard to dissolve, and in the case of copper sulfate it was necessary to use hot water to obtain the required concentration.

The problem of treating large trees must also be considered. It will be noted that the results shown apply only to elm trees under 12 inches in diameter. In field treatments during the spring of 1938, however, approximately 5,000 trees were treated and only 11 trees were encountered which were 20 inches or more in diameter. By materially increasing the dosage per diameter-inch these large trees

[10] See footnote 6.

for the most part were effectively treated. An examination of 10 trees treated with liquid copper sulfate and ranging in diameter from 20 to 30 inches revealed only 1 tree badly infested. A total of 774 sections, each 4 feet in length, from these 10 large trees were stripped of bark and examined. Thirty-two, or 4 percent, of the total sections were infested, and 15 of these 32 sections were from 1 tree. It is believed that the poor results in this tree were accounted for by its shape, and that the results might have been greatly improved if a collar had been placed on each branch of a fork which occurred about 5 feet above ground level. In these 10 trees the dosage had been increased from 60 to 120 grams per inch diameter.

Another consideration is the effect the chemical treatment has on the fuel value of the wood. All that can be said on this is that certain tests conducted by the Dutch Elm Disease Eradication unit of the Bureau of Entomology and Plant Quarantine indicated that the burning of wood from elm trees treated with copper sulfate caused some corrosive action on the stove or furnace.

SUMMARY

Studies made from 1936 to 1938, inclusive, have shown it to be possible to kill elm trees, without rendering them liable to bark-beetle attack, by introducing certain chemicals into the sap stream.

Such a method has been sought because of the difficulties encountered in effectively destroying the many wild elm trees that are possible harborers of the Dutch elm disease fungus (*Ceratostomella ulmi*). Cutting and burning alone does not prevent the sprout growth that will quickly replace the trees.

The materials used most commonly were saturated water solutions of copper sulfate and of sodium arsenite and dry granular copper sulfate, used at dosages of from 15 to 120 grams of the dry salt per inch diameter of the tree.

The chemicals were applied by putting them into watertight bands fastened around the trunk where the bark had been cut through.

Many of the treated trees were examined later for bark-beetle broods, and some so that the extent of the distribution of the chemical throughout the tree might be studied.

Considerable difference was noted between the results of treatments while the trees were in leaf and those made while the trees were dormant, the former being the most effective.

There was no sprouting from the stumps of trees killed with the solutions of copper sulfate and sodium arsenite, but those treated with the dry copper sulfate sprouted vigorously.

Tests were also made with 34 other chemicals, of which zinc chloride was used most extensively, it having been applied on 850 trees at a cost of 69 cents per tree. Water solutions of sodium arsenite, copper sulfate, ammonium bifluoride, zinc chloride, copper nitrate, and copper chloride were effective in killing elm trees and preventing sprouting from the roots.

Of approximately 5,000 elm trees treated in 1938 the greater part were from 3 to 12 inches in diameter and only 11 were over 20 inches. Materially increased dosages per inch of diameter were used on these larger trees, and only 1 of 10 examined later was found to be badly infested.

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